

**WE CLAIM:**

1. A method for repairing a defect in a metallic substrate using welding, the substrate having a first surface and a second surface, the method comprising:

5 a) placing a consumable filler slug in contact with the substrate in the vicinity of the defect;

b) transmitting electrical current from a first electrode to a second electrode in the vicinity of the defect for a period, thereby resistively heating the consumable filler slug and the metallic substrate resulting in coalescence in a substantially liquid pool that substantially fills the  
10 defect, the first electrode and the second electrode applying pressure to the substantially liquid pool;

c) cooling the substantially liquid pool to solidification under the pressure of the first electrode and the second electrode producing a repaired metallic substrate; and

d) removing the first electrode and the second electrode from contact with the repaired  
15 metallic substrate.

2. The method of claim 1, further including the step of applying a sacrificial retainer between the consumable filler slug and the first electrode through which the current passes and resistively heats, a portion of the sacrificial retainer coalescing into the pool and a portion of the  
20 retainer remaining solid and constraining the flow of the pool and sealing the pool from the surrounding atmosphere.

3. The method of claim 1, wherein the defect is a void extending from the substrate first surface to the substrate second surface.

4. The method of claim 3, wherein the consumable filler slug includes a first slug section  
5 and a second slug section, the first slug section having a retaining lip configured to be in contact with the substrate first surface and the second slug section having a retaining lip configured to be in contact with the substrate second surface such that as current passes from the first electrode to the second electrode and resistively heats the first slug section and the second slug section a portion of each retaining lip coalesces into the pool and a portion of each retaining lip remains  
10 solid to constrain the flow of the pool.

5. The method of claim 1, further including the step of applying a first sacrificial retainer between the consumable filler slug and the first electrode and applying a second sacrificial retainer between the consumable filler slug and the second electrode, wherein the void is  
15 substantially cylindrical in shape, having a diameter and a volume, and the consumable filler slug is substantially cylindrical having a diameter smaller than the diameter of the void, a volume, and a distal end and a proximal end whereby the consumable filler slug is configured to be received by the void, such that current passes and resistively heats the sacrificial retainers and the consumable filler slug and a portion of the sacrificial retainers coalesce into the pool and a  
20 portion of the retainers remain solid and constrain the flow of the pool and seal the pool from the surrounding atmosphere.

6. The method of claim 1, wherein the electrical current is substantially uniformly transmitted from the first electrode to the second electrode thereby substantially symmetrically resistively heating the consumable filler slug and the metallic substrate and substantially uniformly heating the defect.

5

7. The method of claim 1, wherein the period of transmitting electrical current from the first electrode to the second electrode is less than approximately 200 milliseconds.

8. The method of claim 1, wherein less than approximately 5% of the heat input to the consumable filler slug and the metallic substrate by the transmission of current from the first electrode to the second electrode remains in the repaired metallic substrate upon removal of the first electrode and the second electrode.

9. The method of claim 1, wherein the amount of cooling applied to the pool is varied as the pool solidifies to achieve a desired predetermined property.

10. The method of claim 9, wherein the desired predetermined property is a preferred grain size.

11. The method of claim 1, wherein the consumable filler slug is composed of the same material as the substrate.

12. The method of claim 1, wherein the repaired metallic substrate is substantially free of distortion.

13. The method of claim 1, wherein the repaired metallic substrate is substantially free of  
5 solidification cracks.

14. The method of claim 1, further including a step of removing excess consumable filler slug material, after the electrodes are removed, so that the surface of the repaired defect is substantially consistent with the level of the adjoining substrate surface.

10 15. A method for repairing a defect in a metallic substrate using welding, the substrate having a first surface and a second surface, the method comprising:

a) placing a consumable filler slug in contact with the substrate in the vicinity of the defect;

15 b) transmitting electrical current substantially uniformly from a first electrode to a second electrode in the vicinity of the defect for a period, thereby substantially symmetrically resistively heating the consumable filler slug and the metallic substrate resulting in coalescence in a substantially liquid pool that substantially fills the defect, the first electrode and the second electrode applying pressure to the substantially liquid pool;

20 c) cooling the substantially liquid pool to solidification under the pressure of the first electrode and the second electrode producing a repaired metallic substrate;

d) removing the first electrode and the second electrode from contact with the repaired metallic substrate; and

e) removing excess consumable filler slug material so that the surface of the repaired defect is substantially consistent with the level of the adjoining substrate surface.

16. The method of claim 15, further including the step of applying a sacrificial retainer  
5 between the consumable filler slug and the first electrode through which the current passes and resistively heats, a portion of the sacrificial retainer coalescing into the pool and a portion of the retainer remaining solid and constraining the flow of the pool and sealing the pool from the surrounding atmosphere.

10 17. The method of claim 15, wherein the defect is a void extending from the substrate first surface to the substrate second surface.

18. The method of claim 17, wherein the consumable filler slug includes a first slug section and a second slug section, the first slug section having a retaining lip configured to be in contact  
15 with the substrate first surface and the second slug section having a retaining lip configured to be in contact with the substrate second surface such that as current passes from the first electrode to the second electrode and resistively heats the first slug section and the second slug section a portion of each retaining lip coalesces into the pool and a portion of each retaining lip remains solid to constrain the flow of the pool.

20 19. The method of claim 15, further including the step of applying a first sacrificial retainer between the consumable filler slug and the first electrode and applying a second sacrificial retainer between the consumable filler slug and the second electrode, wherein the void is

substantially cylindrical in shape, having a diameter and a volume, and the consumable filler slug is substantially cylindrical having a diameter smaller than the diameter of the void, a volume, and a distal end and a proximal end whereby the consumable filler slug is configured to be received by the void, such that current passes and resistively heats the sacrificial retainers and the consumable filler slug and a portion of the sacrificial retainers coalesce into the pool and a portion of the retainers remain solid and constrain the flow of the pool and seal the pool from the surrounding atmosphere.

20. The method of claim 15, wherein less than approximately 5% of the heat input to the consumable filler slug and the metallic substrate by the transmission of current from the first electrode to the second electrode remains in the repaired metallic substrate upon removal of the first electrode and the second electrode.

21. A method for repairing a defect that is a substantially cylindrically shaped void in a metallic substrate using welding, the substrate having a first surface and a second surface, and the void extending from the first surface to the second surface, the method comprising:

a) placing a substantially cylindrical consumable filler slug in the void and applying a first sacrificial retainer on the first surface and a second sacrificial retainer on the second surface such that the first sacrificial retainer and the second sacrificial retainer cover the void and the consumable filler slug;

b) transmitting electrical current substantially uniformly from a first electrode to a second electrode in the vicinity of the void for a period of less than approximately 200 milliseconds while applying pressure to the first sacrificial retainer and the second sacrificial retainer, thereby

substantially symmetrically resistively heating the first sacrificial retainer, the consumable filler slug, the metallic substrate, and the second sacrificial retainer resulting in coalescence of a portion of the first sacrificial retainer, the consumable filler slug, a portion of the substrate, and a portion of the second sacrificial retainer in a substantially liquid pool that substantially fills the  
5 void while being retained by the first sacrificial retainer and the second sacrificial retainer;

c) cooling the substantially liquid pool to solidification under the pressure of the first electrode and the second electrode producing a repaired metallic substrate such that less than approximately 5% of the heat input to the consumable filler slug and the metallic substrate by the transmission of the current remains in the repaired metallic substrate and the repaired metallic  
10 substrate is substantially free of distortion;

d) removing the first electrode and the second electrode from contact with the first sacrificial retainer and the second sacrificial retainer; and

e) removing excess consumable filler slug material so that the surface of the repaired defect is substantially consistent with the level of the adjoining substrate surface.

15